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Development of SCADA Using Petri Net Algorithm for Batch Process Plant

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Abstract : Petri Net has gained increased usage and acceptance as a basic model of systems as an asynchronous concurrent computation. This paper searched the basic concepts and usage of the classical method Petri Net algorithm in SCADA system to control and monitoring the process plant. The structures of the Nets, their makings and execution, several examples of Petri Net models of controlling and monitoring and research into the analysis of the Petri Nets are presented, as the use of the reachability tree and decidability and complexity of some Petri Nets problems. This paper has presented a framework for designing and implementing a PN-based supervisory for remotely control systems with the human in the loop. Petri Nets are used in designing the supervisory system that yield a compact graphical model for the remote model in real time applications.

Keywords: Algorithm, modelling, Petri Net, SCADA System

1.0 INTRODUCTION

Our approaches ensure that algorithm and remote control operations give safety requirements for the system. Based on the remote control systems, certain human operations may violate desired safety requirements and result in catastrophic failure. This paper systematically approaches to develop supervisory agents, which guarantee that remote manual operations meet safety specifications. By applying the mutual exclusive concept, the Petri Net approach is used to model, design and verify a supervisory system, which prevents human errors. This methodology is adopted to implement the supervisor as an intelligent agent for online supervision of the remote control system. To demonstrate the feasibility and practicability of the developed supervisory approach, we apply it to a single tank batch plant. In general, Petri Net is a graphical, mathematical and process modelling tool for engineers in automatic control and computer science and is applicable to many systems. It plays a major role in the work on improving the batch control. Petri Net can be applied to event related process control in simulating, checking, debugging, and stating the quantitative deviations from the ideal solutions of any given continuous or discrete process as well as providing formal checking at all development stages from specification, design and implementation. As a graphics tool, Petri Net can be used as a visual-communication aid similar to the flow charts, networks, and block diagrams, whereby as a mathematical tool, Petri Nets is possible to set up state equations, algebraic equations, and other mathematical models governing the behaviour of a system. From the information of the Petri Net analysis, performance of the system can be evaluated and hence it is expected that the plant technologists (engineers and operators) can derive some suggestions and making changes on the system for improvement.

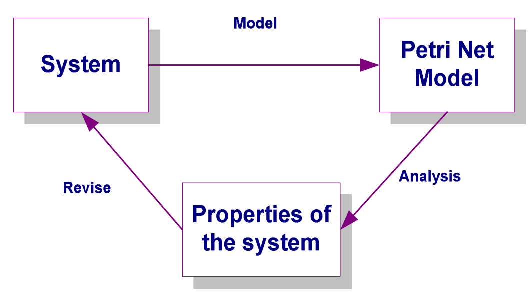

Fig. 1 The algorithm approach to the system.

The practical application of Petri Net to design and analysis of the systems can be accomplished in several ways. One approach considers Petri Net as an auxiliary analysis tool. For this approach, conventional design techniques are used to specify a system. Any problem encountered in the analysis point flaw in the design. The design must be modified to correct the flaws. This modified design can be done, and then be modelled and analyzed again. This cycle is repeated until the analysis reveals and no unacceptable problems in the design (Fig. 1 shows the design concept in the Petri Net algorithm).

2.0 HISTORY PETRI NET

Carl Adam Petri introduced Petri net in 1960 – 1962. He was a contemporary German mathematician who defined a general-purpose mathematical tool for describing relations existing between conditions and events. His works on these Nets have resulted in considerable research, some in the United State (notably Institute of Technology) in the early seventies, and in Europe ever since. Since 1962, a considerable work has been done in both the theory and application of Petri Nets mainly in the areas of computers (hardware and software), computer networks, communication protocols, operating systems, production control systems, factory automation, modelling of discrete event system and actual manufacturing systems[1][2][3]. In general, Petri Net is a graphical, mathematical and process modelling tool for engineers in automatic control and computer science and is applicable to many systems. It plays a major role in the work on improving the batch control. Petri Net can be applied to event related process control in simulating, checking, debugging, and stating the quantitative deviations from the ideal solutions of any given continuous or discrete process as well as providing formal checking at all development stage from specification, design and implementation.

As a graphics tool, Petri Net can be used as a visual-communication aid similar to the flow charts, networks, and block diagrams, whereby as a mathematical tool, Petri Nets is also possible to set up state equations, algebraic equations, and other mathematical models governing the behaviour of a system.

Additionally, the analysis of Petri Net can reveal useful information about the structure and dynamic behaviour of the modelled system. From the information of the Petri Net analysis, the performance of the system can be evaluated and hence it is expected that the plant technologists (engineers and operators) can derive some suggestions and making changes on the system for improvement.

2.1 Basic Concept on Petri Net

Petri Net is both graphical and mathematical modelling tool. As a graphical tool, Petri Net can be used as a visual communication aid similar to the flow charts, block diagrams, and networks. Basically Petri Net divided by two major techniques. First technique we call it, a Classical Method and second technique High Level Method. Fig. 2 - shows the types of Petri Nets. In this paper, we mightily concentrate only on the classical method.

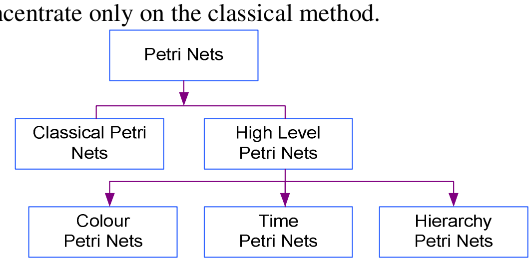

Fig. 2 Types of Petri Nets

2.2 Basic Structure of Petri Net Algorithm

The basic concept of the Petri Net structures we are shows in Fig. 3. Input function ***I*** is a mapping from a transition t_j to a collection of places $I(t_j)$. Input places of a transition is denoted by $I(t_j)$, Output places of a transition is denoted by $O(t_j)$.

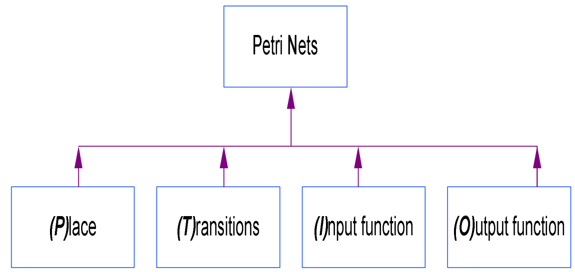

Fig. 3 Petri Net Structure

The Petri net structure consists of a set of places $P = (p_1, p_2, p_3 \ldots p_n)$, a set of transitions $T = (t_1, t_2, t_3 \ldots t_m)$, and the input and output function is (***I*** and ***O***). The input ***I*** define, for each transition ***t***, the set of input places for the transition, $I(t)$. Similarly, the output function ***O*** defines, for each transition of set $O(t)$ of output places for the transition. These four items define the structure of a Petri net, hence four – tuples formal definition of a Petri net, C :

$$C = (P, T, I, O)$$

The example of a Petri net structure defined as four – tuples are given. A solid circle is a movement token.

$$C = (P, T, I, O)$$
$$P = (P_1 , P_2, P_3, P_4)$$
$$t = (t_1 , t_2)$$
$$I(t_1) = (P_1)$$
$$I(t_2) = (P_1,P_2)$$
$$O(t_1) = (P_2 ,P_3)$$
$$O(t_2) = (P_4)$$

3. 0 STATE SPACE EQUATION

The dynamic behaviour of many systems studied in engineering can be described by differential equation or algebraic equations. It would be nice if we could describe and analyze completely dynamic behaviour of Petri Nets by some equations. In the strength of mind, this manuscript presents matrix equations that govern the dynamic behaviour of concurrent systems modelled by Petri Nets. However, the solvability of these equations is somewhat limited, partly because of the nondeterministic nature inherent in Petri Net models and because of the constraint that solution must be as non-negative integers.

The event driven system of a Petri Net is fully define by the expressions, namely: the initial condition, the switching (firing) equation and the switching condition. Each one of them marked by one token per relevant place by, and is express by the $n-dimensional$ marking vector $x(k)$. The initial marking (state) is given by $x(0)$. The switching equation describes the progress of the process control system and the process plant from the stage k to the $k+1$,

3.1 Mathematical Modelling

The modelling is based on discrete event system using state equations. The progress of the process control system and process plant from stage k+1 is described directly by a fundamental equation, which is called the switching (firing) equation, that is,

$$x_{(k+1)} = x(k) + H \bullet u(k) \text{, k = 0, 1, 2, . . .} \qquad (1)$$

where x(k) :is a marking state row vector of order n, its element $x_i(k)$ is the number of tokens in place p_i and x(0) is the initial marking state of x(k); H : is the (*n* x *m*) place-to-transition incidence matrix. It describes the directed connections of n places and m transition and is given by :

$$H = H^{+} - H^{-} \qquad (2)$$

Where H^+ is the post-condition (*n* x *m*) matrix, output to transitions and H^- is the pre-condition (*n* x *m*) matrix, the inputs to the transitions; u(k) : is the m-dimensional switching or control vector, has zeros everywhere except for the element corresponding to transitions that are fired at the firing instant. (Its components are '1'for transition with switched, '0'for all non-switched transitions) which is, given by the switching,

$$\text{vector (k)} = \theta[H^{-T}(x(k) - 1N)] \qquad (3)$$

such as, that diagonal matrix is given by :-

$$\theta : \theta = \begin{pmatrix} \vartheta_1 & & 0 \\ & \ddots & \\ 0 & & \vartheta_m \end{pmatrix} \text{ where } H^T$$

is the transpose of matrix H^T. $\tau_{ja} = v(a) = 1$ (for a $\geq$ 0, switching transitions), $\tau_{ja} = v(a) = 0$

(for a $\langle$ 1 , non-switching transitions).

4.0 REAL TIME PETRI NET

Based on the state space equations as we discussed before, Petri Net algorithm is a one of the method for an industrial to develop an application tools for manufacturing plants. It is an automatically generate the control and monitoring coding given by a Petri Net algorithm. One of the central tasks in this paper, we develop a Petri Net compiler for Petri Net controllers such as that a Petri Net representation can be converted into a Programmable Logic Controller like a supervisory for the industrial applications. Therefore, to develop a compiler for general purpose becomes a challenging mission in this paper.

Based on that reason, we explored and make a philosophical statement research to develop software or system that reader can use this system and easy to understand the Petri Net algorithm theory in their design. The basic structure of software development will be shown in Fig. 4.

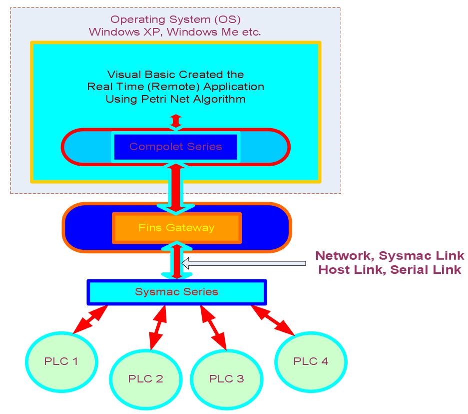

Fig. 4 Integrated tolls for Software development

A possible architecture includes a Petri net compiler, is a Petri net interpreter for Batch process plant. Real time software was created and it allows user to calculate and test their design whether it is reachable or unreachable system, before they (the users) develop the actual systems. When the final result is reachable, the users can compare it with the final marking, proof that the system is reachable and stable to design. At the same time user can used this software to control and monitoring their batch process plant. Fig. 5 shows the Batch system and Petri Net interpreter.

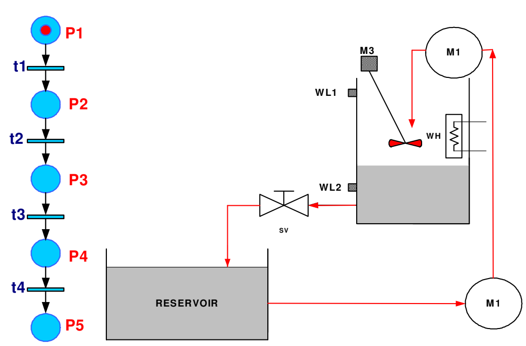

Fig. 5 Petri Net an interpreter for Batch System

In other word, for the first steps of the process setup, the user must fill in the stage level of the process. Fig. 6 shows how to insert the number of stages level. Every stage represents sub process of the Batch plant.

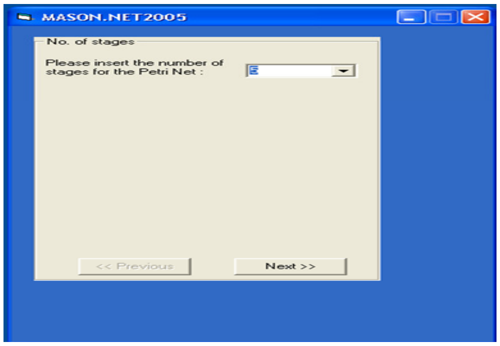

Fig. 6 Insert the number of stage level for Batch process

For the following steps, user must fill up the number of place at every stage. Fig. 7 shows the number of place and transition process. Simultaneously, this software automatically draws the place and transition of the first stage process. In this part, software automatically generated the interfacing code and output bit to communicate with the PLC (OMRON).

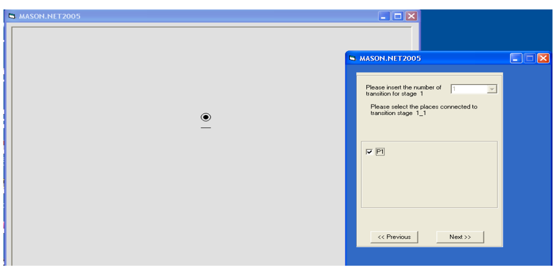

Fig. 7 Setup the place and transition format for stage 1

Based on the state space equation, refer to equation 1.2. User needs to insert the pre-condition and post-condition of the system design. Fig. 8 shows the result of the pre-condition and post-condition of the Batch plant (single tank system).

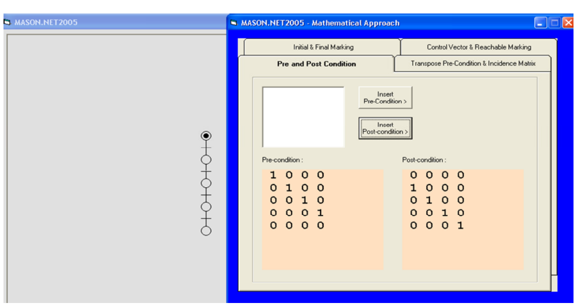

Fig. 8 Pre-condition and post-condition

Regarding on the State Space Petri Net algorithm, user must insert the value of initial and final marking value. All the values in this system are important in this algorithm system. Beside that user can use the value to find the firing vector to run the calculation code in this system. Fig. 9-11 shows the method to insert initial and final marking value.

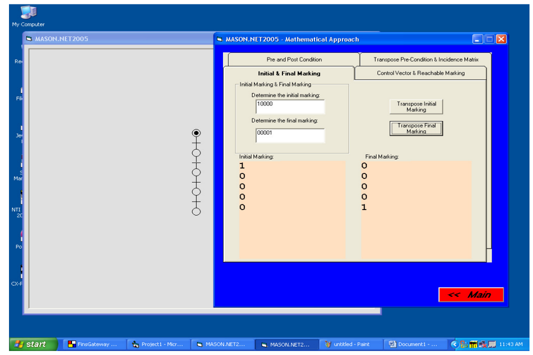

Fig. 9 Initial and final making values

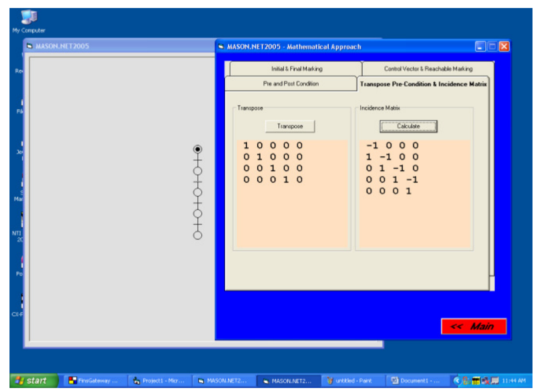

Fig. 10 Calculate the incident matrix

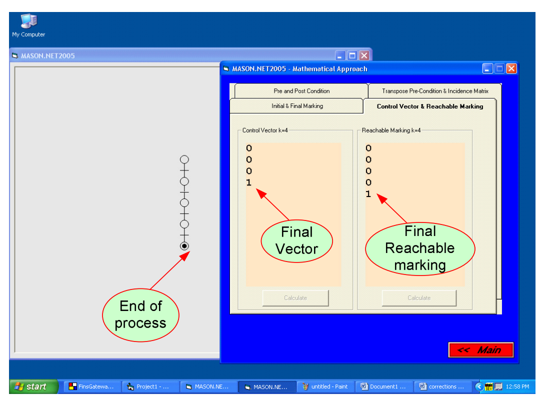

Fig. 11 Calculate the final firing vector

5.0 REMOTE SYSTEM DEVELOPMENT

The purpose of a supervisory system is to provide user with the capability to exercise control over a specific device and to confirm its performance in accordance with the directed action. The commonly used name is supervisory control and data acquisition (SCADA) system. The smallest supervisory system it terms of master and remote stations is single master or single remote, usually referred to as one-on-one system.

Today, a one-on-one system is typically a special case of a small SCADA or Remote System. Moving up in the size, there is the single master, multiple remote systems. In many application systems, this is considered to be a small system, which is a limited number of remote terminal units (RTUs) may be controlled. As the size of the system increases, the major change is usually in the number of RTUs, number of application program or special functions, and the sophistication and customization of the interface between the user and the system.

This interface has been referred to as the man-machine interface (MMI), but today it is called the user interface (UI). At some point, the system clearly becomes a large one. Large system can include multiple master stations or sub-master stations, and the RTUs can number in the hundreds. Such systems often involve extensive engineering and customization. Fig. 12 shows a block diagram of a typical supervisory system. Fig. 13 shows the structure of development system. We integrated the Petri Net algorithm or Mathematical algorithm into the Remote SCADA for Batch process plant to control and monitoring the process.

6.0 CONCLUSION

This paper advocates the use of the high level information already available in the requirement phase, to set up the Real – time Remote System using Petri Net Algorithm, that is to say the identification of the model components, of their interactions and of the performance and dependability indices of the interest. The application of

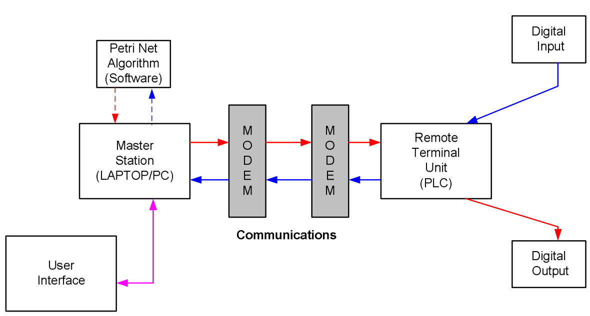

Fig. 12 Setup remote system

Petri Nets is through modelling. In many fields of study, a phenomenon is not studied directly but indirectly through a model of the phenomena. A model is a representation, it is hoped that knew knowledge about the modelled phenomenon could be obtained without the danger, cost, or inconvenience of manipulating the real phenomenon itself.

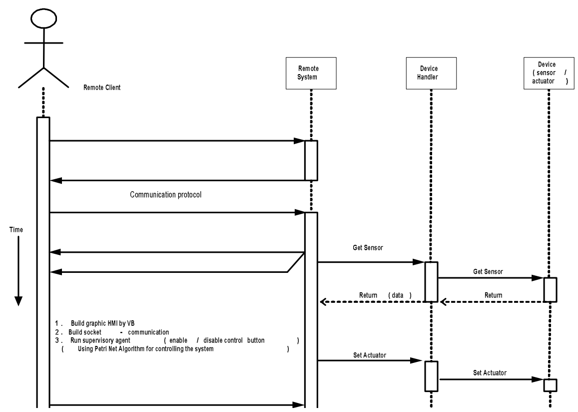

Fig. 13 The layer of remote communication system

Most of modelling use mathematics algorithm. The important features of many physical phenomena can be described numerically and the relations between these features described equations or inequalities. Particularly in the natural sciences and engineering, properties such as mass, position, momentum and force are described by mathematical equations. Because of it, Petri Net will widespread in the recent industrial technology. By using this method, we hoped the entire user could develop and use this method to design system on his own without the error or danger to the designer.

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